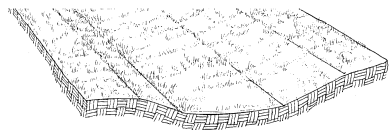
- DRAFT -
Vegetated ~~Infiltration~~ Swale
(1005)

~~Interim Technical Standard~~
Wisconsin Department of Natural Resources
Conservation Practice Standard

I. Definition

Vegetated ~~infiltration~~ swales are storm water conveyance systems designed to achieve water quality and quantity benefits.~~enhance the infiltration runoff.~~ ~~A vegetated infiltration~~Vegetated swales can be ~~a~~ natural elongated depressions or ~~a~~ constructed channels. ~~A vegetated infiltration swale differs from a conventional drainage channel or ditch in that it is constructed specifically to promote infiltration.~~



II. Purposes

The ~~primary~~ purposes of this practice ~~is~~ are to filter and trap pollutants, improve water quality, attenuate peak flow, and/or promote infiltration ~~e storm water,~~ while limiting groundwater contamination. ~~by providing filtering of pollutants. Vegetated swales can also help attenuate peak flows through reducing runoff velocities and volumes.~~

III. Conditions where Practice Applies

~~Vegetated infiltration swales are best suited for~~
- ~~*low- to medium-density residential land uses*[1], and~~
- ~~Non-residential areas where infiltration of runoff is allowable under Chapter NR 151.~~

~~Swales are often placed along roads and in drainage easements in side/back lot lines.~~ This standard applies to new vegetated swales. Refer to WDNR Guidance for evaluation of existing swale systems. Swales are intended to treat relatively flat ~~and small~~ drainage areas with contributory areas less than 5 acres. Swales are not suitable in areas of steep topography or areas with erodible soils without ~~implementation of additional~~ measures to reduce flow velocities and protect against erosion.

Vegetated swales are best suited for use:

A. In low- to medium-density residential areas with 7 units per acre or fewer;

B. In non-residential areas where infiltration of runoff is allowable under ch. NR 151, Wis. Adm. Code;

C. Along roads and drainage easements;

D. In meeting the swale treatment option in chs. NR 151 (subchapter IV, Transportation Facility Performance Standards), Wis. Adm. Code;

E. With other control practices, such as filter strips, wet detention ponds, and bioretention devices.

~~This standard does not apply to swales installed to meet the swale treatment option set forth in ss. NR 151.24(10) and Trans 401.106(10).~~

Conservation Practice Standards are reviewed periodically and updated if needed. To obtain the current version of this standard, contact your local WDNR office or the Standards Oversight council office in Madison, WI at (608) 833-1833.

IV. Federal, State, and Local Laws

Users of this standard shall be aware of potentially applicable Federal, State, and local laws, rules, regulations, or permit requirements governing vegetated ~~infiltration~~ swales. This standard does not contain the text of Federal, State, or local laws.

V. Criteria

Vegetated ~~infiltration~~ swales may be used independently or as a component of a storm water conveyance/storage system, and in either case shall be designed in accordance with the following:~~to infiltrate runoff and can be a component of a system intended to meet the runoff infiltration requirements of Chapter NR 151. The swale may also be a component of the stormwater conveyance/storage system.~~

A. Site Assessment

1. To obtain performance standard or Total Maximum Daily Load (TMDL) credit for infiltration and/or pollutant loading reduction, conduct and document a~~A~~ site assessment ~~shall be conducted and documented~~in accordance with ~~meeting the requirements of the~~ WDNR Conservation Practice Standard "Site Evaluation for Stormwater Infiltration" (1002).

2. For transportation projects (III.D) not required to meet performance standards or TMDL reduction, conduct a site assessment of sufficient detail to establish site-specific conditions, including but not limited to soil types and depth to seasonal high groundwater.~~In addition, the site assessment shall evaluate the alignment of the infiltration swale in relation to ground slopes; drainage patterns; and proximity to buildings.~~

B. Site Layout – ~~The~~ In the site layout, identify vegetated swale location in relation to and in consideration of ~~shall consider features such as location of infiltration swales relative to~~ buildings, water supply wells, karst, lot boundaries, site topography, drainage patterns, and existing or proposed public rights-of-way, easements, as well as other environmental and regulatory items of concern. Chapter NR 151 Wis. Adm. Code specifies required minimum separation distances.

1. ~~Where~~ If a swale accepts runoff from more than one property, ~~it shall be located~~locate the swale in a ~~legally~~ legally-established drainage easement granting access for maintenance, or in a public right-of-way.

2. ~~Swales shall~~Do not ~~be~~ *hydraulically connect*[1] swales~~ed~~ to foundations and do not locate swales where they~~or~~ cause negative impacts to structures.

3. Do not locate s~~S~~wales ~~shall not be located~~ such that overflow from the swale could cause flooding of existing or proposed buildings, roads, or adjacent properties during storms with recurrence intervals commensurate with the degree of hazard.

4. Identify how and where runoff from each drainage area will enter the swale, either as *sheet flow* over the side of the swale, or from a concentrated source such as a pipe or curb cut. Describe the flow path of runoff from source areas through pre-treatment devices and into swales. Examples include:

   a. Sheet flow off road surface to road shoulder, to *vegetated filter strip* for pre-treatment prior to a vegetated swale.

   b. Upstream pre-treatment device, such as a wet detention pond, into a pipe discharging into a vegetated swale.

[1] *Words in the standard that are shown in italics are described in Definitions Section IX. The words are italicized the first time they are used in this text.*

5. If swales are located such that the bottom of the swale is at or below the seasonally high groundwater level, set the infiltration rate for that portion of the swale to zero in the model.

C. **Modeling Parameters –** Use an *approved model* to quantify infiltration volume and/or pollutant load reduction provided by vegetated swales. The swales used in the models are those that meet the criteria of this standard. When modeling, do not include segments of the swale that do not meet velocity and depth requirements in section V.D. When modeling, do not combine swale segments that have significantly different flow depths, flow velocities, or infiltration rates unless the most conservative values are applied to all segments (steepest slope, narrowest bottom width, lowest infiltration rate, etc.). The modeling parameters are defined below.

1. Average swale length to outlet (feet) is used if the analysis incorporates particulate pollutant reductions due to filtering or settling. The average swale length to outlet is defined as the total swale length if the swale conveys runoff from an upstream point source to a downstream discharge point with little additional runoff added to the swale between the upstream and downstream points.

   If a swale network conveys runoff from a drainage area with multiple defined point source inputs or sheet flow, then the average swale length is defined as the average of half of each swale segment length in the drainage area served by swales.

$$\mathbf{SL_{avg} = [(SS_1/2) + (SS_2/2) + \ldots + (SS_n/2)] / n}$$

   Where:
   SL_{avg} = Average Swale Length to Outlet (feet)
   SS_n = Swale Segment Length
   n = Number of Swale Segment Lengths

2. *Design infiltration rate* (inches/hour) is the dynamic infiltration rate of the swale (one-half of the static infiltration rate to account for flowing water). See Section V.I.4 for equation.

3. Rainfall (inches) data that is used in the analysis shall be appropriate for the site as determined by the *administering authority*.

4. Total swale length (feet) is the total length of all swales in the drainage area developed in accordance with this standard.

5. Swale densities (feet/acre) are the total swale length divided by the treated drainage area. Calculate swale densities for each drainage area.

6. Swale geometry includes side slopes, longitudinal slopes, and bottom width (V.E.) of the typical swale in the drainage area being analyzed. Swales with significant variations in width, longitudinal slope, bottom width, and/or drainage area along their length should be divided into segments modeled in series to account for these variations.

7. Swale retardance factor describes the type and height of the grass which is then used to determine the Manning's *n* value used in the equations provided in HEC-15 (September 2005) and as extended by Kirby and others (2005). Vegetated swales typically have a retardance factor represented by Retardance Class C or D.

8. Total Tributary Drainage Area (acres) is the drainage area served by the swale including the area of the swale.

9. Vegetation height (inches) is the typical height of vegetation in the swale. Pollutant reduction varies with the vegetation height, type, and density.

~~C.~~D. **Velocity and Depth ~~Criteria~~** – ~~A~~ The maximum velocity of runoff into and through a vegetated swale shall not cause the swale system to become unstable (such as through erosion, sediment resuspension, scour, etc.), and shall ~~is based on providing~~allow adequate residence time for infiltration~~, allowing for a stable swale design, and preventing re-suspension and scour of sediment~~.

1. ~~Peak flow velocity f~~For the 2-year, 24-hour design storm, do ~~shall~~ not exceed 1.5 feet per second peak flow velocity, and do not exceed a 12-inch flow depth ~~have a maximum flow depth of 12-inches~~. For ~~larger~~ design storms greater than the 2-year, 24-hour, velocities shall be non-erosive for finished grade soil with *established vegetation*.

2. Select Manning's roughness coefficients, "*n*", ~~shall be selected~~ consistent with the type of vegetation, mowing height, and depth of flow as determined using HEC-15. Attachment ~~2~~ 1 ~~provides guidance on selection of~~ illustrates the variation in Manning's *n* values for ~~shallow~~ various flow depths ~~of flows~~.

   ~~When calculating the infiltration volume, if the approved model does not vary Manning's *n* with the depth of flow, a default value of 0.30 can be used for the Manning's n provided the flow depth does not submerge the vegetation.~~

3. If allowed by the regulatory authority, install ~~D~~ditch checks~~, if allowed by the regulatory authority, shall be installed~~ as necessary to reduce velocities, extend detention time, or retain a design volume. Refer to WDNR Conservation Practice Standard ~~Technical Standard 1062~~ "Ditch Checks" (1062) for design requirements.

   ~~If utilizing~~Design ditch checks so standing water drains~~, ensure that the design allows for no standing water~~ within 24 hours after a rainfall~~/~~-runoff event. If using wet-tolerant vegetation, standing water must drain within 48 hours of the rainfall/runoff event.

~~D.~~E. **Swale Geometry ~~Criteria~~**[2] –

1. Design ~~sS~~swales ~~shall have~~with side slopes no steeper than three horizontal to one vertical (3:1) for trapezoidal ~~channels and 4:1 for~~or triangular ~~shaped swales~~swale cross sections. Use ~~F~~flatter side slopes if possible to reduce erosion and increase infiltration ~~are recommended to reduce erosion potential and increase infiltration area~~.

2. ~~The~~ Design the bottom width of ~~the~~ swales ~~is shape dependent but shall be a maximum of 6-feet~~with trapezoidal cross section to be no more than 8 feet wide to minimize channelization. If widths greater than ~~6~~8 feet are needed, ~~then~~ use a triangular cross-section with shallow side slopes (as flat as 20:1) with appropriate erosion control matting, or length-wise dividers ~~shall be employed~~ so~~such~~ that the maximum bottom width of any given cell is ~~6~~8 feet.

3. Design ~~tT~~the longitudinal slope of the swale ~~shall~~ to be between 0.5~~1~~% and 4%. Slopes less than 1% with infiltration rates below 0.13 inches/hour must be planted with wet-tolerant vegetation.

~~E.~~F. **Vegetation** –

1. ~~Swales shall be planted~~Plant swales with native vegetation or ~~seeded with~~ turf grass. If sod grown in muck soil is used~~Sod shall not be used. Sod~~ for infiltration swales, use a static infiltration rate of no more than 0.05 inches per hour. ~~does not establish roots as well as seed and often has muck soils not conducive to infiltration.~~

2. Provide ~~A~~ site-specific planting information ~~guide shall be prepared for~~with ~~each~~ project plans and specifications.

[2] *This standard does not set forth criteria for the analysis of site hydrology, system hydraulic analysis for large flows, or channel stability. See Reference Section X.*

3. Use a~~A~~ companion or~~(~~ cover~~)~~ crop ~~may be necessary for establishing~~if needed to establish native vegetation. Care should be taken with proper selection of companion or cover crop since many seed mixes are already formulated to address this issue.

4. Select ~~Depending on location of the swale,~~ vegetation ~~shall be selected~~ that is tolerant of road salt and wetness, depending on swale location.

~~1.~~5. Install a~~A~~ planting medium that can support the selected vegetation ~~shall be installed~~.

~~2.~~6. To maintain typical swale vegetation, design~~infiltration~~ swales ~~shall be designed~~ to have no standing water within 24 hours after a rainfall~~-~~/~~-~~runoff event. If wet-tolerant vegetation is established, standing water must drain within 48 hours of the rainfall/runoff event.

~~F.~~G. **Construction ~~Criteria~~**

1. Prepare a construction erosion and sediment control plan**.**

2. Where swales are proposed in filled areas, specify in the plans that fill used in the swale area is a soil type consistent with the infiltration rate assumed in the modeling.

3. If possible, construct swales off-line. Bring swales on-line after the vegetation is established and the contributing watersheds are fully stabilized. The swale shall be brought on-line when the area draining to the basin has achieved 90% *build out* of all lots in any of the first 3 years or 75% build out in any subsequent year. By 5 years from the start of construction in the drainage area, all vegetated swales shall be brought on-line.

4. Where swales cannot be constructed off-line, such as in the case of a road ditch or construction conveyance channel that is intended to serve as an infiltration practice post-construction, follow one of these approaches:

    a. Construct and stabilize the swale as early in the construction process as possible to allow the vegetation to become established before receiving large quantities of runoff. Install and maintain effective erosion and sediment controls to prevent swales from receiving construction site sediment, which is difficult to remove from an established swale without destroying the vegetation.

    b. If grading plan provides sufficient elevation, temporarily leave swales one foot above finished grade to protect the infiltration capacity. Excavate to final grade once the site is stabilized. Protect and stabilize swale as specified in V.G.4.c. below.

    c. Construct the swales as part of the overall grading plan, but do not finish the swales until the rest of the construction is completed and the contributing watershed has been stabilized by following these steps:

        i. Stabilize adjacent construction areas. After the tributary areas are stabilized, remove any sediment that entered the swale during construction.

        ii. Then, stabilize the swale itself following any compaction mitigation or addition of necessary soil amendments.

        iii. If the swale infiltration capacity has been reduced from silt or clay sediment, excavate the top 1 foot of soil and replace with *engineered soils* or appropriate native soils that provide infiltration characteristics to meet the modeling requirements.

        iv. Refer to WDNR Conservation Practice Standards “Channel Erosion Mat” (1053), “Mulching for Construction Sites” (1058), and “Seeding for Construction Site Erosion Control” (1059).

5. During construction there may be a delay between the initial road construction and installation of utilities outside of the swales. To address compaction and sediment deposition from utility installation, follow one of these approaches:

   a. Complete swale construction immediately following road completion, and then protect the swales as aggressively as possible during utility installation, using construction fencing, biologs, etc.

   b. Stabilize the swales following road construction using topsoil, temporary seeding, and erosion control matting. Following utility installation, complete the swale stabilization. This may entail sediment removal, compaction mitigation, soil amendments, installing erosion control matting a second time, and seeding with the permanent seed mix.

   c. Avoid placing utility easements within the swale boundary.

6. To address swale compaction, use one of the following options:

   a. Avoid swale compaction during and after construction. Keep vehicles and equipment with ground pressure equal to or greater than 5 pounds per square inch (PSI) out of swales at all times.

   b. Mitigate swale compaction by one or more of the following methods:

      1) Use a chisel plow or rotary tillage device, capable of reaching 12 inches below the surface, to incorporate four inches of compost per WDNR Specification "S100 Compost". Keep vehicles and equipment with ground pressure equal to or greater than 5 PSI out of swales after mitigation is completed.

      2) Replace native soil within the bottom width of the swale and over the *effective infiltration area*, with at least 18 inches of engineered soil. Engineered soil shall be *subsoiled* or installed in lifts with the first lift of 4 to 6 inches of engineered soil incorporated into the native soil. Keep vehicles and equipment with ground pressure equal to or greater than 5 PSI out of swales after mitigation is completed.

   c. If swale compaction is not avoided or mitigated as described in items V.G.6.a or V.G.6.b above, refer to Section V.I.3 to determine the appropriate infiltration rate.

~~1. Following excavation, exclude vehicles and heavy equipment from entering the infiltration swale area to prevent compaction. To minimize or mitigate the effects of compaction during construction and to control soil erosion associated with construction:~~

~~2. Compaction Mitigation – The effects of compaction shall be mitigated using the following methods:~~

   ~~a. Incorporate soil additives consisting of two inches of *compost* and two inches of topsoil.~~

   ~~b. The compost shall be incorporated into the existing soil using a chisel plow or rotary device with the capability of reaching to 12 inches below the existing surface.~~

   ~~c. The compost component shall meet Wisconsin Department of Natural Resources Specifications S100 Compost.~~

~~3. A construction erosion control plan shall be prepared. Prior to compaction mitigation and final grading of the infiltration swale, the drainage area to the swale shall have proper erosion controls in place to prevent sediment from entering the swale, and the lot(s) adjacent to the swale shall be stabilized. Any sediment entering the swale during construction shall be removed after the tributary area is stabilized. The infiltration swale itself shall also be stabilized following compaction mitigation and final grading. Stabilize swale prior to receiving runoff. For stabilization design criteria for tributary areas and the swale itself, refer to WDNR~~

~~Conservation Practice Standards Channel Erosion Mat (1053), Mulching for Construction Sites (1054) and Seeding for Construction Site Erosion Control (1059).~~

~~G.~~ **Pre-treatment** ~~-~~ – As with other infiltration devices, vegetated ~~infiltration~~ swales require pre-treatment of storm water to remove sediment from source areas listed in s. NR 151.124(7) ~~(5)(c)~~ ~~(4)~~ Wis. Adm. Code ~~Pretreatment can be accomplished through the use of practices such as grassed swales, detention basins, and vegetated filter strips~~. Pre-treatment is intended to prevent clogging of the infiltration system and protect groundwater. For vegetated swales, many contaminants are mitigated in the soil column, and vegetation prevents clogging. Therefore, the pre-treatment options below are intended to protect swale vegetation, mainly to allow for settling of larger particles that could smother vegetation.

~~H. If a pre-treatment swale is used, the length of pre-treatment shall be calculated based on the following equation with a minimum length of 200 feet:~~

~~**L** = **v** * **HRT** * 60s/m~~

~~Where:~~

~~**L** = Swale length in feet~~

~~**v** = Peak flow velocity in fps for 2-year, 24-hour design storm~~

~~**HRT** = Hydraulic residence time in minutes shall be either:~~

- ~~5 minutes for infiltration rate greater than or equal to 0.5 inches per hour (sandy loam).~~
- ~~8 minutes for infiltration rate less than 0.5 inches per hour (sandy loam).~~

~~Infiltration rates shall be determined in accordance with WDNR Conservation Practice Standard Code 1002, "Site Evaluation for Stormwater Infiltration."~~

H. ~~If a pre-treatment swale is used, the area of the pre-treatment swale shall not be counted toward the effective infiltration area~~

The area of any pre-treatment practice does not count toward the effective infiltration area. For vegetated swales, pre-treatment can be accomplished through the use of the following practices (see Attachment 2 for pre-treatment diagrams):

1. *Vegetated Filter Strip* – Vegetated filter strips can pre-treat sheet flow. Use level spreaders, grading, and shaping to convert concentrated flow to sheet flow before reaching filter strips. Design vegetated filter strips with a maximum flow depth of ½ inch, and a slope not steeper than 4:1, except for roadways, where a slope as steep as 2.5:1 is allowed. Determine if the filter strips satisfy the pre-treatment requirement:

   a. Ten or more feet of filter strip flow length is sufficient for pre-treatment of sheet flow runoff into swales.

   b. If there is less than five feet of filter strip flow length, the filter strip does not count toward pre-treatment, and an alternate pre-treatment method must be used.

   c. For filter strip flow length five feet or greater, but less than ten feet, use the procedure in Attachment 3 to account for the deficient filter strip flow length.

   d. Filter strips are not an adequate pre-treatment measure when receiving runoff from more than 100 feet of flow from impervious and/or non-vegetated areas.

2. Vegetated Swale – Vegetated swales can pre-treat concentrated flow from point sources such as pipes and curb cuts. When calculating the effective infiltration area, subtract the pre-treatment swale area (multiply 80 feet of swale length by the swale wetted perimeter (see Attachment 4)) from the total infiltration area.[3]

[3] *This is based on a Stokes' law calculation using approximately 1 foot flow depth, 1.5 feet per second flow velocity, and 100-micron particle size.*

3. *Sedimentation Device* – Sedimentation devices can accept sheet flow and/or concentrated flow for pre-treatment. Design the sedimentation device to capture at least a 100-micron particle size, which equates to approximately 10% *NURP* total suspended solids reduction.

4. Other Device – To the extent technically and economically feasible, minimize the level of pollutants infiltrating to groundwater though use of pre-treatment devices for the pollutants of concern.

I. **Infiltration –** To meet the infiltration performance standards of s. NR 151.124 Wis. Adm. Code, a swale must meet the following:

1. If a pre-treatment swale is used, the area of the pre-treatment swale shall not be counted toward the effective infiltration area

2. **Determination of** ***Effective Infiltration Area*** – Use the following equation to calculate – In order to take credit towards the infiltration requirements in NR 151.12(5)(c), the swale must meet the criteria outlined in this standard.

1. The effective infiltration area is the area that can be counted toward the rrequirements in s. NR 151.124 Wis. Adm. Code (5)(c) and is calculated based on wetted perimeter of the vegetated infiltration swale:

$$A = P * L$$

Where:
A = effective infiltration area in square feet
P = wetted perimeter (at one-inch flow depth) in feet
L = length of vegetated swale in feet

at a flow depth of 1-inch multiplied by the length of vegetated infiltration swale.

*Effective Infiltration Area (ft²) = ½ * Wetted Perimeter (ft) at 1-inch depth of flow * Length of Vegetated Infiltration Swale (ft)*

Details on the See Attachment 4 for calculation methodology can be found in Attachment 1.

Pre-treatment areas do not count toward the effective infiltration area. Vegetated infiltration swales receiving runoff from source areas identified in outlined under s. NR 151.124(7) Wis. Adm. Code (5)(c)(4) cannot be counted toward the effective infiltration area unless the water is effectively pre-treated prior to entering the swale. The area of the pre-treatment device shall not be counted toward the effective infiltration area.

2. Infiltration Volume – Use an approved model to quantify the volume of water infiltrated and the resulting pollutant reduction.

3. Static Infiltration Rate – The design infiltration rate is a function of the static infiltration rate. Use one of these approaches to determine the static infiltration rate:

   a. Use WDNR Conservation Practice Standard "Site Evaluation for Stormwater Infiltration" (1002) to determine static infiltration rate based on soil type.

   b. If conducting site-specific infiltration tests at design bottom elevation of the swale and conducting compaction mitigation as specified in V.G.6.b.1): follow WDNR Conservation Practice Standard "Site Evaluation for Stormwater Infiltration" (1002), except that the WDNR modified (2-hour) double ring infiltrometer test may be used and infiltrometer test results may be used for the static infiltration rate.

c. If conducting site-specific infiltration tests at design bottom elevation of the swale but not mitigating for compaction in accordance with V.G.6.b: follow WDNR Conservation Practice Standard "Site Evaluation for Stormwater Infiltration" (1002) to determine static infiltration rate, except that the WDNR modified (2-hour) double ring infiltrometer test may be used.

d. If mitigating for compaction using engineered soil as described in V.G.6.b.2): either use the infiltration rate for sand in WDNR Conservation Practice Standard "Site Evaluation for Stormwater Infiltration" (1002) and apply the appropriate correction factor based on underlying soil type, or use 0.42 inches per hour[4] as the static infiltration rate.

4. ***Design Infiltration Rate*** – Use the following equation to calculate the design infiltration rate – The *design infiltration rate* for swales:

(K_{swale}) shall be ½ the infiltration rate (K_{static}) determined in accordance with WDNR Conservation Practice Standard Code 1002, "Site Evaluation for Stormwater Infiltration." This is to account for the dynamic nature of a swale in which water is moving through the system rather than the static nature of the infiltration tests where the water is allowed to pond.

$$K_{swale} \text{ (inches/hr.) } = \tfrac{1}{2} * K_{static}$$

Where:

K_{swale} = design infiltration rate in inches per hour

K_{static} = static infiltration rate in inches per hour determined in accordance with WDNR Conservation Practice Standard "Site Evaluation for Stormwater Infiltration" (1002)

½ = safety factor to account for the dynamic nature of a swale through which water is moving, compared to the static nature of an infiltration test in which water is ponded

Infiltration Volume Credit – The volume of water infiltrated and the resulting pollutant reduction must be quantified through the use of an *approved model*.

VI. Considerations

These additional factors are set forthThe following considerations are intended to enhance the use of this practice, or to address special cases that may arise in the implementation of the practice.

A. Swales should be designed to have hydraulic capacities that meet applicable local government or state agency requirements for conveying runoff from large storms, and they should also be designed as part of a *major stormwater management system* as defined in this standard.

B. The number and length of swales is dictated by the topography and amounts of runoff from the contributing area. For a given depth of flow, the width of a swale depends on the rate and velocity of flow through the swale. Minimum length and width requirements to achieve infiltration and water quality improvements may limit the use of a swale at some sites.

C. The eEstablishment of deep-rooted vegetation will enhance infiltration.

D. Underdrains may be added to swales with less than 1% slope to limit inundation. Plant wet-tolerant vegetation if the drawdown time exceeds 24 hours.

D.E. Swale performance may change over time due to site-specific conditions, such as vegetation characteristics, maintenance, sediment deposition, compaction, etc. Follow the most recent WDNR guidance that specifically addresses evaluation of existing swales.

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[4] *This is based on assuming 3.6 inches per hour for sand and dividing by 8.5, the most conservative correction factor in the WDNR Conservation Practice Standard "Site Evaluation for Stormwater Infiltration" (1002).*

E.F. Conduct soil tests to determine the amount of fertilizer needed to establish or maintain *dense vegetation*.Swale geometry should attempt to maximize the infiltrative surface but avoid convergence of flows that may result in erosion or gullies.

F.G. Excavation hoes, light equipment with turf-type tires, marsh equipment, or wide-track loaders that have ground pressure equal to or less than 5 PSI should be used to construct swales and minimize compaction. Heavier equipment may require compaction mitigation.

G.H. Public education is recommended to inform local residents of the swale's' purpose and to discourage dumping of leaves or parking within swales or on the edge of the swales.

I. This infiltration device is Vegetated swales are not suitable for treating chlorides. Chloride use onde-icer use within source areas tributary to a swale can be reduced or eliminated by minimizing the amount of compound used, using alternative de-icers, or using clean sand.

H.J. To protect groundwater, if site information indicates compliance with a preventative action limit (in accordance with ch. NR 140 Wis. Adm. Code) is not achievable, a vegetated swale may not be installed or shall be modified to prevent infiltration to the maximum extent practicable.

VII. —Plans and Specifications

Plans and specifications shall be prepared in accordance with the criteria of this standard and shall describe the requirements for applying the practice to achieve its intended use. Plans shall specify the materials, construction processes, locations, size and elevations of all components of the practice to allow for certification of construction upon completion.

VIII. Operation and Maintenance

Prepare a site-specific annual An operationinspection and maintenance plan for the specific swales that addresses the following: shall be prepared. The responsible party shall be identified.

A. Identify the responsible party.

B. Limit off-street parking or other activities that may cause rutting or soil compaction in the swales and repair as needed.

C. Annually inspect swales to detect and remedy nuisance conditions such as standing water, weeds, woody growth, and trash dumping. Limit the use of pesticides and fertilizer if swale is used for water quality control.

D. Pesticides and fertilizer shall be used in moderation, and only if needed to establish or maintain dense vegetation.

E.

F.D. Maintain the proper design height for dense vegetation when mowing or cutting.Vegetation shall be mowed or cut such that the proper design height is maintained. To take credit for potential phosphorus removal by the swale, mowed/cut vegetation must be removed as part of routine maintenance.

G.E. Sediment shall be removed Remove sediment when infiltration rates are impeded, sediment accumulation is visible, or if standing water exists for 48 hours after a rainfall/runoff eventsediment reaches a height of 2 inches. Minimize serious disturbance of the vegetation and aAvoid compaction of the soil in the swale during the sediment removal process. After sediment removal, repair any damaged or eroded areas by filling with topsoil that meets appropriate infiltration requirements. If compaction occurs, restore the swale infiltration capacity by mitigating for compaction. Mitigation practices can include subsoiling, chisel plowing, or soil aeration. Reseed as needed to reestablish vegetation Fill any eroded areas with topsoil and reseed.

F. Implement erosion control measures if erosion If during construction or maintenance erosion becomes severe enough to prevent establishment of vegetation, additional erosion control measures shall be taken. Refer to WDNR Conservation Practice Standards "Channel Erosion Mat" (1053), "Mulching for Construction Sites" (105884), and "Seeding for Construction Site Erosion Control" (1059) for further guidance.

~~When maintenance is required the infiltration capacity of the swale shall be restored. Vegetation shall be reestablished following compaction mitigation.~~

~~Annual inspections shall be made to detect and remedy nuisance conditions such as mosquitoes, weeds, woody growth and trash dumping.~~

IX. Definitions

Administering Authority (V.C.3.): State and/or local units of government with stormwater management regulatory authority.

Approved Model (V.C.~~E.~~): A computer model with an infiltration component that adequately accounts for the hydraulic nature of swales and that has been approved by the applicable regulatory authority. Examples include SLAMM, P-8, and RECARGA.

Build Out (V.G.2): Build out means that the lot has been fully developed and stabilized from erosion.

~~*Compost* (J.1.): A mixture that consists largely of aerobically decayed organic waste.~~

Dense Vegetation (VIII.4.): A stand of 3 to 12-inch high grassy vegetation that uniformly covers at least 90% of a representative 1 square yard plot.

Design Infiltration Rate (V.C.2.~~V.D.~~): A velocity, based on soil structure and texture, at which precipitation or runoff enters and moves into or through soil. The design rate is used to size an infiltration device or system. Rates are selected to be minimal rates for the different types of soils. Selection of minimal rates will provide a robust design and maximize the longevity of the device.

Effective Infiltration Area (V.G.6.b.2.~~V.B.~~): The area of the infiltration system that is used to infiltrate runoff. Does not include the area used for pre-treatment.

Engineered Soil (V.G.4.c.iii.): A prescribed mixture of soil meeting the most recent version of WDNR Conservation Practice Standard "Bioretention for Infiltration" (1004) or most recent guidance regarding engineered soil.

Established Vegetation (V.D.1): A uniform perennial vegetative cover of at least 70% density.

Hydraulically Connected (V.B.2.~~I.~~): Two entities are considered to be hydraulically connected if a surface or subsurface link exists between the two exist such that water is transmitted from one entity to the other.

~~*Low-density Residential Land Use* (III): Single-family houses on lots with areas of 19,000 square feet or greater.~~

Major Storm W~~w~~ater Management System (VI.A): The storm water management facilities that are intended to convey and/or store runoff in excess of the capacity of the minor system. The minor system is designed to function frequently to prevent nuisance flooding and is sized for a smaller storm than the major system, generally a 10-year storm. The major system is primarily designed to function infrequently to prevent flooding of buildings and ponding of runoff in locations where it could promote harmful infiltration and inflow to sanitary sewers. The major system is generally designed for a 100-year storm. It consists of the components of the minor system, such as overland flow, swales, curbs and gutters, storm sewers, and detention/retention basins, and also includes the entire roadway cross section and associated swales or overland flow paths ultimately discharging to receiving streams.

~~*Medium-density Residential Land Use* (III): Single-family houses on lots with areas ranging from 10,900 to 18,999 square feet.~~

NURP (V.H.3.): NURP stands for National Urban Runoff Program and in this document refers to the NURP particle distribution. See Attachment 5 and the USGS website (http://www.usgs.gov/) for more information.

Sedimentation Device (V.H.3.): Examples of sedimentation devices that could be used for swale pre-treatment may include wet detention ponds (Wisconsin DNR Conservation Practice Standard #1001), proprietary sedimentation devices, catch basins, and hydrodynamic devices.

Sheet flow (V.B.4): A maximum ½-inch height of flow evenly spread over the filter strip width, for runoff events using the average annual rainfall as defined in s. NR 151.002 Wis. Adm. Code.

Subsoiled (V.G.6.b.2.): A form of deep tillage to break up the soil layers and reduce compaction, which can improve infiltration, drainage, and root penetration. If the swale is to be subsoiled, conduct the following:

1. After topsoil placement, use equipment capable of exerting necessary penetration force to drag tines, shanks or claws through the soil to a depth of approximately 20 inches to loosen the soil and mix the soil layers. Subsoil the swale three times to mix the topsoil and base soil. Do not pull the shanks through previous channels, but instead create multiple channels in the swale.
2. At a minimum, line up shanks behind the vehicle tracks to mitigate compaction.
3. If soils are saturated, delay operations until the soil moisture is less than or equal to "field capacity," which is the amount of water retained in the soil after it has been saturated and allowed to drain freely.
4. Schedule a 50-foot long test section to demonstrate the subsoil process prior to completing the balance of the work.
5. Finish grading the surface (prior to seed preparation) with tracked equipment with a track pressure no greater than 5 PSI to minimize compaction.

Vegetated Filter Strip (V.B.4.a.): Vegetated filter strips (grassed filter strips, filter strips, and grassed filters) are vegetated surfaces designed to treat sheet flow from adjacent surfaces. Filter strips function by slowing runoff velocities and filtering out sediment and other pollutants, and by providing some infiltration into underlying soils.

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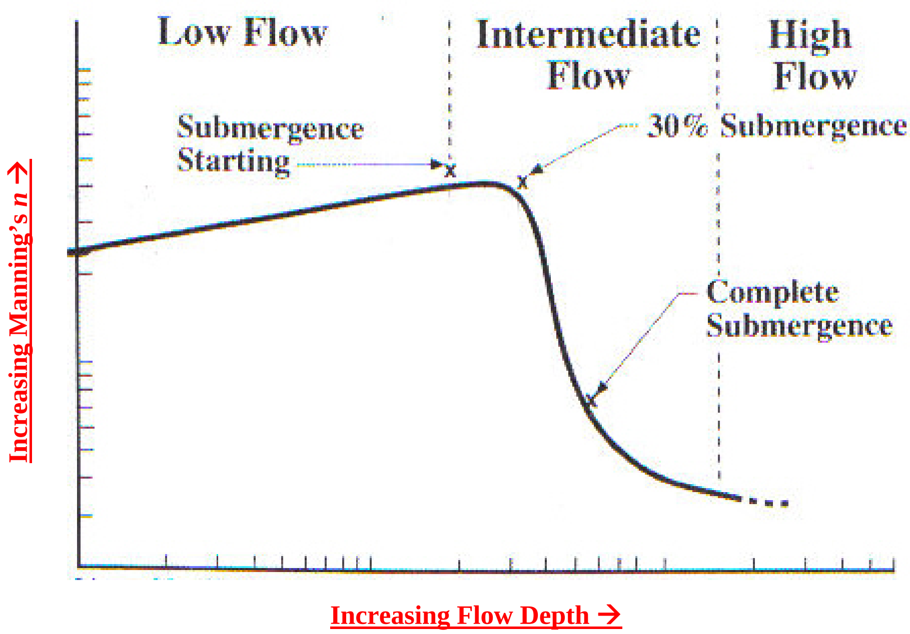
Attachment ~~2~~1:
~~Calculation~~ Illustration of the Change of Manning's *n* Values with Flow Depth
Vegetated ~~Infiltration~~ Swales (1005)

Manning's *n*, the roughness coefficient, varies with the type and height of vegetation and the depth of flow. Typically, vegetation creates a significant flow resistance at lower flows when the grass remains erect and the water surface is below the top of the vegetation. Vegetated infiltration swales are designed to convey runoff from smaller more frequent storm events and thus at lower flow depths than typically encountered using the typical design-storm methodology (i.e. 2-year or 10-year storm). Figure 1 shows a variation of Manning's n with flow depth. Figure 1 assumes dense turf type vegetation mowed to a height of 4-inches. For design, calculate Manning's *n* values using equations in HEC-15. ~~This is consistent with published values that show a Manning's *n* value of 0.030 for short turf grass under higher flow conditions (Chow, 1959) in which the vegetation is submerged.~~

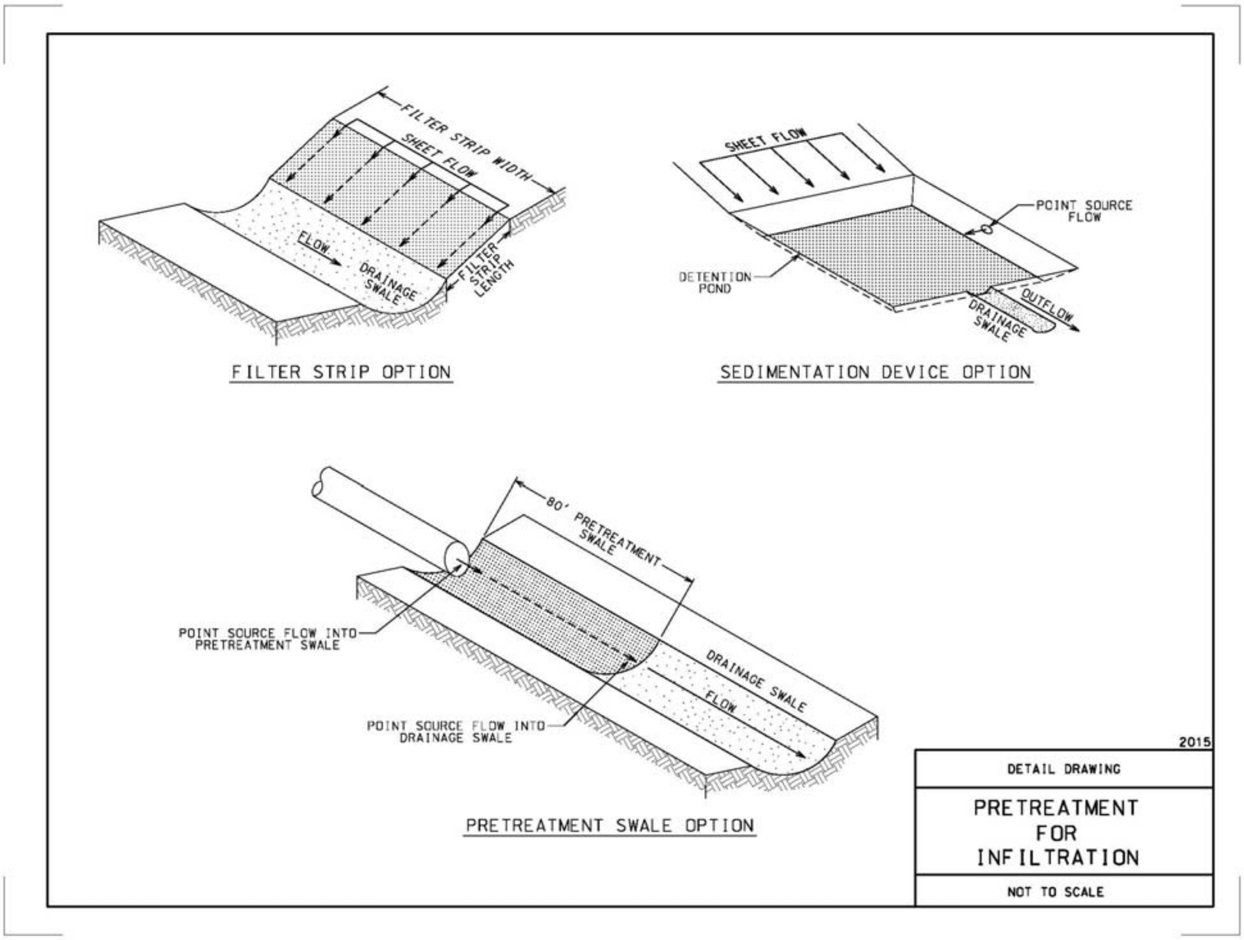
Figure 1: Manning's *n* Under Different Flow Depths



~~Source~~Modified from: Minton 2005

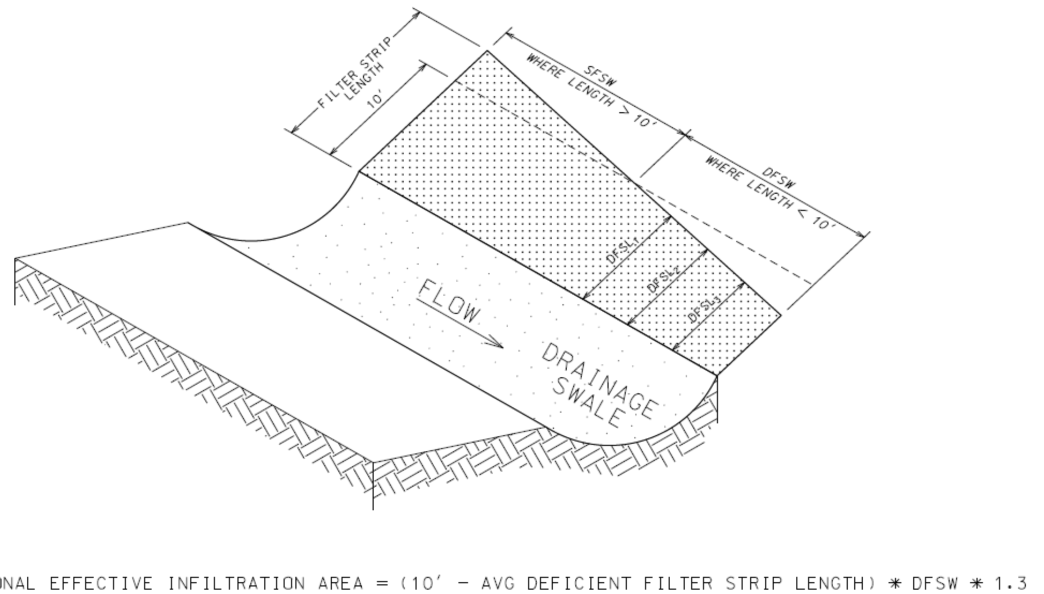
Research has shown that Manning's *n* can be related to the product of the flow velocity and the hydraulic radius. This relationship is further dependent again on the type and height of vegetation. Currently, data does not exist for native prairie vegetation.

Attachment 2:
Pre-Treatment Options for Swales
Vegetated Swale (1005)



Attachment 3:
Deficient Filter Strip Length
Vegetated Swale (1005)

Use this method to address pre-treatment in situations where there is insufficient filter strip flow length (between five feet and less than ten feet).



The Additional Effective Infiltration Area (AEIA) required to compensate for using filter strips less than 10 feet (and at least 5 feet) in length can be calculated using the figure above for reference and the following steps:

1. Determine the deficient filter strip width (DFSW) in feet. This is the cumulative width of filter strip where the filter strip flow path length is less than 10 feet (but at least 5 feet).

2. Determine the average filter strip length (DFSL) in feet in the DFSW. Use a minimum of three distances within any deficient segment of filter strip. One measurement must include the shortest filter strip flow path length in the DFSW.

3. Calculate the Additional Effective Infiltration Area (AEIA) required to compensate for the deficient filter strip. Use the equation:

AEIA = (10 feet – Avg. DFSL) * DFSW * 1.3

The AEIA is the area of swale or other infiltration area that does not count toward the site's effective infiltration area. A maximum of 80 feet of swale length would not be considered "effective infiltration area" for each drainage area (up to five acres) served by swales.

Attachment ~~1~~4:
Calculation of Effective Infiltration Area
Vegetated ~~Infiltration~~ Swales (1005)

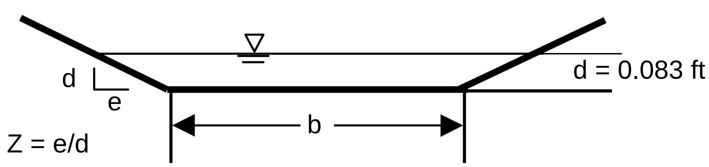
The effective infiltration area as outlined in ch. NR 151 Wis. Adm. Code is defined as the area of the infiltration system that is used to infiltrate runoff and does not include the area used for site access, berms, or pre-treatment. The area of infiltration is calculated for a swale based on the wetted perimeter of the swale. However, the swale is rarely flowing at capacity under the numerous smaller rainfall events that dominate an average year, so the wetted perimeter at the design capacity of the swale (typically a 2-year or 10-year storm) is not appropriate. The effective infiltration area is determined as follows:

Effective Infiltration Area (ft^2) = ~~½ *~~ Wetted Perimeter (ft) * Length of Vegetated Infiltration Swale (ft)

For the purpose of ch. NR 151 Wis. Adm. Code, the wetted perimeter will be calculated at a 1-inch (0.083 feet) depth of flow. The 1-inch depth of flow is intended to simulate the water quality volume. ~~The multiplication by ½ is to account for the reduced infiltration rate in swales compared to other practices such as infiltration basins were water is allowed to pond.~~ Wetted perimeter can be calculated as outlined below.

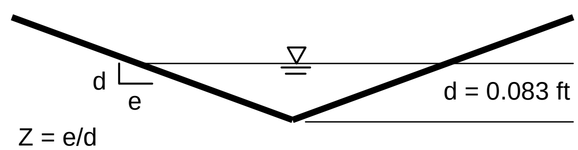
Trapezoidal Channel Cross section:

Wetted Perimeter, p
$p = b + 2d\,(Z^2 + 1)^{1/2}$



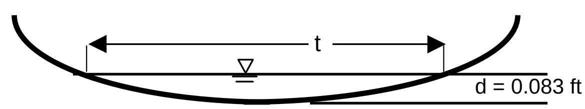
Triangular Channel Cross section:

Wetted Perimeter, p
$p = 2d\,(Z^2 + 1)^{1/2}$



Parabolic Channel Cross section

Wetted Perimeter, p	Top Width of flow, t	Cross-sectional Area of flow, a
$p = t + (8d^2) / (3t)$	$t = a / (0.67d)$	$a = 2/3\,(t\,d)$



Attachment 5:
NURP Particle Size Distribution
Vegetated Swale (1005)

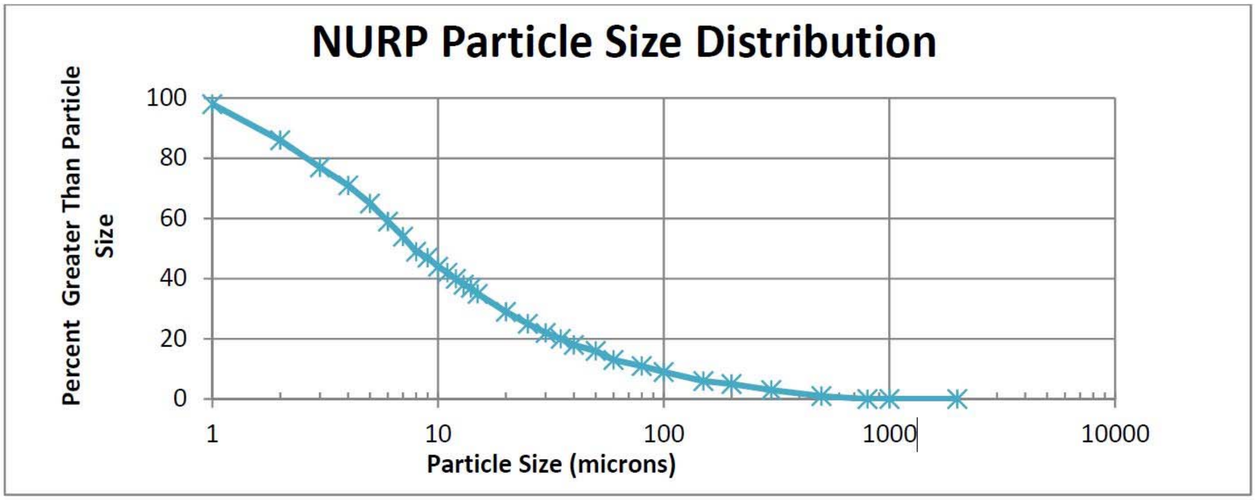


Image Source: Burton, A.G., and Pitt, R., 2002